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High Level Assessment of Modular Pumped Hydro at the San Juan Coal Mine and Generating Station in Farmington, New Mexico

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Introduction

This high level assessment was written from notes taken during San Juan Coal Mine and Generating Station Trip on May 17, 2019 by the authors. The objective was to tour facilities at the mine and power plant to assess potential for Modular Pumped Hydro (MPH) Applications.

MPH is a scaled-down closed-loop cycle version of conventional pumped hydro, with two reservoirs (either manmade or natural) located at different elevations, connected by appropriate pressurized water conveyance path (i.e. penstock), reversible pump/turbine, and transformers. Refer to Figure 1 for a general layout view of the MPH energy storage concept. With MPH, both reservoirs are intended to be covered and lined to manage water losses, and water is reused over-and-over again. Depending upon location though, the lower reservoir may be a river, in which case the water would not be reused. The scaled-down version allows direct integration into communities where closed-loop cycles or conventional pumped hydro would never be applicable. In this case, scale enables design. MPH was selected for review because of the technology's superior performance, longevity, minimum cost to operate & maintain, potential to interface with existing or new water systems, and complementary solar siting option[1].

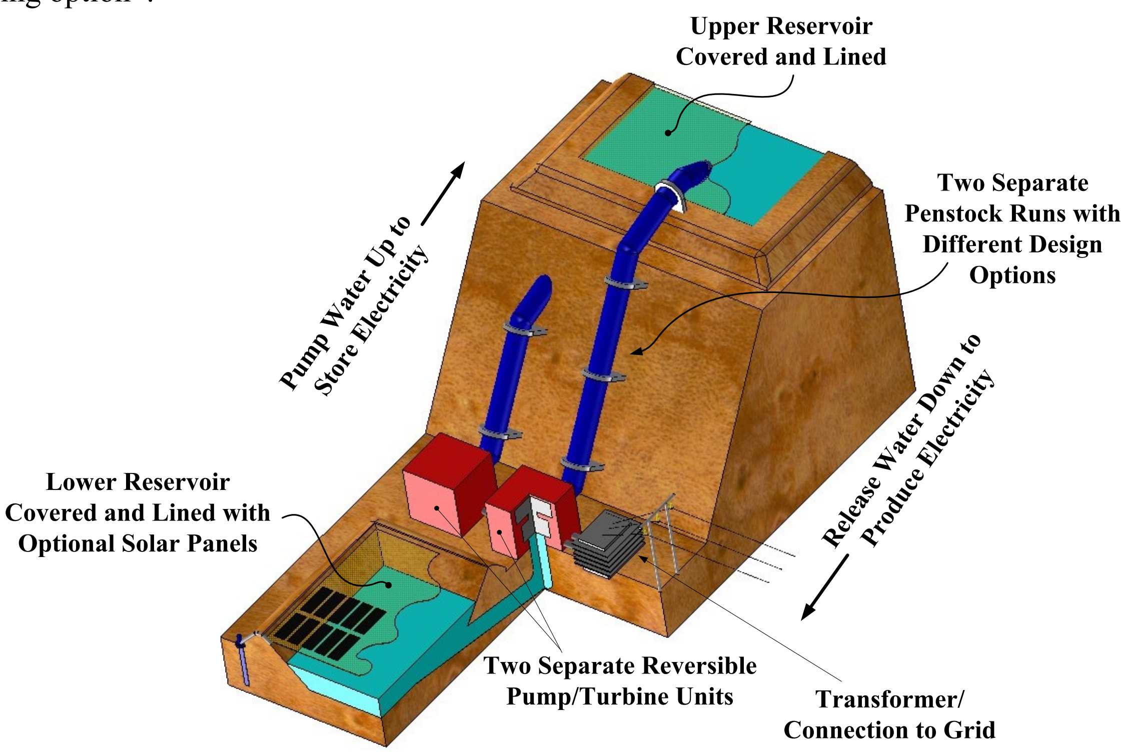

Figure 1: General layout view of the Modular Pumped Hydro energy storage concept. Two penstock design options are shown for display purposes only. Reservoirs could be replaced with large tanks.

[1] Mark L. Bibeault and William L. Kubic Jr, "Sustainable Energy Storage Feasibility Study for Santa Fe Community College", LAUR-14-26026, December 4, 2014.

The coal fired power plant was built at this location approximately 45 years ago because the coal was co-located and there was no rail (and still is none) available to move the coal. Both the coal fired power plant and mine are currently slated to be closed before January 2023 unless new buyers take over the operations. PNM desires to investigate future revenue options. Daniel Mumm of Westmoreland provided our mine tour, with Omni Warner, Plant Director, and his staff, providing the power plant tour. The sizing calculations for the four cases mentioned below are given in the attachment.

Mine Review

- Reclamation efforts underway which include filling the pit with fly and bottom ash. In addition, the high clay content of the overburden makes for highly unstable soils.
- Best potential may be the existing ventilation shafts that run from the surface to approximately 400 feet underground to the three transport tunnels. Each tunnel is large enough to accommodate a mining truck and measures roughly 20'x20' and extends more than 3 miles.
- The three tunnels could potentially store 150 million gallons (460 acre-ft) of fluid, and the ventilation shafts could provide roughly 400 feet of head offering approximately 150 MWh of electrical energy storage potential at 80% roundtrip efficiency (Case A). An upper reservoir would need to be constructed, and the structural integrity/sealing capability of the mine would have to be verified/improved.
- Powerlines nearby and some existing impoundment basins.

Generating Station Review

- Multiple acres of evaporation ponds at various elevations. According to USGS map
    - Upper pond is at approximately 5360' ASL and lower pond is at 5320' ASL
    - Lake is at 5270' ASL
    - The San Juan River is at approximately 5084 at the River pump station.
- The River pump station is approximately 4 miles (straight-line) from the Lake. SJGS has water rights for about 2/3rds? of current needs with the rest coming from leases.
- The Lake pump station is approximately 1 mile from the powerplant and substation.
- Three river pumps each with a 9,000 gpm capacity
- Multiple Lake pumps with similar total pumping capacity of river station.
- Hypothetical options for pumped hydro near term include using existing upper evaporation pond (30 acre-ft?) and lake 90 ft below for 2.0 MW-hr storage (Case B), or deploying energy recovery pumped units at the river site would provide 1.4 MW-h storage (Case C).
- Hypothetical option for pumped hydro using the lake as an upper reservoir (5*100 = 500 acre-ft?) with an new lower constructed reservoir (assuming 200 ft elevation difference) for up to 82 MW-hr storage (Case D).

In 2016, the New Mexico Energy, Minerals and Natural Resources Department, Energy Conservation and Management Division (ECMD) developed and submitted a grant proposal to the US Department of Energy (DOE) for the creation of an energy roadmap for the state. The overarching goal of the grant proposal was to develop an energy roadmap/plan that would strength and diversity New Mexico's energy economy to be resilient to global changes. The process to develop the Roadmap was designed to be inclusive and stakeholder driven, recognizing that many sectors and resources comprise New Mexico's energy industry. ECMD was awarded $300,000 to develop an energy roadmap over a two year time period: year one (2017) Develop the Roadmap, year two (2018+) Implementation of the Roadmap.

How this effort fits into the New Mexico Energy Roadmap:

Goal 4: Pursue emerging energy technologies through research, demonstration, development and deployment

Strategy 4.a Expand energy storage capacity with examples to include solar plus storage (to support microgrids), thermal storage and pumped hydro-electric.

This effort fits directly under Strategy 4.a of Goal 4.

Strategy 4.f. Consider option for smart siting of clean & renewable energy and storage installations. From the notes/details "Integrate with Goal 5: Optimize NM's electricity transmission system.

This effort at the SJGS takes full advantage of existing transmission infrastructure.

This effort seeks to make use of existing equipment and can potentially make use of a regional supply of oil and gas industry produced water which furthers efforts under produced water Goal 3 in the Energy Roadmap.

SB 489 calls for reinvestment in the San Juan area, including the siting of new energy generation. If solar is the selected new generation, then energy storage is vital to meeting the demands of existing markets. Dispatchability of the power is key to entering the California and other markets including PNM's entrance into the Western Energy Imbalance Market.

Attachment: PNM Case Studies

In all cases considered below, the following variables are consistently utilized between all cases considered:

$\rho := 1000$ density of water, kg/m^3

$g := 9.81$ acceleration of gravity, m/sec^2

For units conversion, 1 MWh = 1000 kWh

Case A: Mine

Note: efficiencies are inclusive of turbine/pump, generator, transformer and penstock losses.

$\eta := .80$ Roundtrip Efficiency

$h := 400 \cdot .3048 = 121.92$ height between reservoirs, m

$\text{volume} := 460$ Define volume of water moved between reservoirs, acre-ft

$\text{volume\_m3} := \text{volume} \cdot 1233.489 = 5.674 \times 10^{5}$ convert to m3

The following flowrate equation was derived from fundamental conservation of energy and mass principals for an incompressible fluid.

$\text{Energy} := (\eta)\cdot(\rho)\cdot(g)\cdot(h)\cdot\text{volume\_m3} = 5.429 \times 10^{11}$ Joules

$\text{Energy} := \text{Energy} \cdot 2.7778 \cdot 10^{-7} = 1.508 \times 10^{5}$ kWhr (approximately 150 MWh)

Case B: Evaporation Pond

$\eta := .75$ Roundtrip Efficiency, slightly lower for small sized system

$h := 90 \cdot .3048 = 27.432$ height between reservoirs, m

$\text{volume} := 30$ Define volume of water moved between reservoirs, acre-ft

$\text{volume\_m3} := \text{volume} \cdot 1233.489 = 3.7 \times 10^{4}$ convert to m3

$\text{Energy} := (\eta)\cdot(\rho)\cdot(g)\cdot(h)\cdot\text{volume\_m3} = 7.469 \times 10^{9}$ Joules

$\text{Energy} := \text{Energy} \cdot 2.7778 \cdot 10^{-7} = 2.075 \times 10^{3}$ kWhr (approximately 2 MWh)

Case C: Energy Recovery

$P := 600$ Horsepower rating of a single unit

$P := P \cdot 745.7 = 4.474 \times 10^{5}$ Convert to Watts

$t := 4$ Define hours of operation to recover energy, hrs

$\eta := .80$ Define efficiency during recovery

$Energy := \eta \cdot P \cdot t = 1.432 \times 10^{6}$ Electrical Energy recovered, Wh

$Energy := \frac{Energy}{1000} = 1431.7$ Convert to kWh (Approximately 1.4 MWh)

Case D: Lake

$\eta := .80$ Roundtrip Efficiency

$h := 200 \cdot .3048 = 60.96$ height between reservoirs, m

$volume := 500$ Define volume of water moved between reservoirs, acre-ft

$volume\_m3 := volume \cdot 1233.489 = 6.167 \times 10^{5}$ convert to m3

$Energy := (\eta) \cdot (\rho) \cdot (g) \cdot (h) \cdot volume\_m3 = 2.951 \times 10^{11}$ Joules

$Energy := Energy \cdot 2.7778 \cdot 10^{-7} = 8.196 \times 10^{4}$ kWhr (approximately 81 MWh)